A Comprehensive Model for Performance Prediction of Electro-Optical Systems

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LONG-TERM GOALS

The EODES suite of electo-optical image simulation and performance prediction models are designed to provide tools for system design and analysis, tactical performance prediction for mine countermeasures (MCM) mission planning, and the generation of synthetic imagery for operator training and the development of automated target recognition systems. Since this three-year project only extended a couple months into FY09, we provide here a brief summary of the entire effort.

OBJECTIVES

EODES electro-optical sensor models are based on high-fidelity physical models of radiative transfer in turbid media under the assumption of small-angle scattering [1] and Fourier optics models for various scanning systems [2,3,4]. A key objective of this program was to develop flexible and efficient numerical solution techniques for these physical models to provide near real-time simulation and analysis, which is an important requirement for tactical performance prediction. Another objective was to demonstrate the performance prediction capabilities, and their potential impact on MCM mission planning, at various naval exercises, including RIMPAC-06, RIMPAC-08, and several MIREM and VULCANEX exercise. Finally, the EODES performance prediction software is currently being certified as a Navy standard model for inclusion in the Oceanographic and Atmospheric Master Library (OAML).

APPROACH

Radiative transfer modeling is based on the small-angle approximation equation first published by Dolin [1]. The model assumes that light undergoes only a small deflection during each scattering event, and that the cumulative effect of many scattering events results in mostly small deviations from the original direction of propagation. This model has been shown to provide excellent approximations to light beam propagation in oceanic and atmospheric environments over several attenuation lengths. EODES implements an efficient solution strategy that includes time-dependence, range-dependent water properties, arbitrary scattering phase functions, and various source radiance distributions.

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Electro-optical scanning systems models are based on the Fourier optics approach provided by Bravo-Zhivotovskiy et al. [2], Wells [3], and Mertens & Replogle [4]. The EODES implementation provides for various types of laser sources (e.g., pencil beam, fan beam, broad beam), continuous wave or pulsed modes, monostatic and bistatic configurations, and active or passive operation. Simulation tools with graphical user interfaces (GUIs) for various types of systems are provided as part of the software package. An example GUI for a laser line scan system is shown on the left of Figure 1. The physical models for radiative transfer and system simulation are described in [10].

The EODES performance prediction model for underwater electro-optical imaging systems is patterned after the General Image Quality Equation [5], which relates an image quality metric to the ground sampled distance (GSD), relative edge response (RER), and the signal-to-noise ratio (SNR). EODES uses the radiative transfer and system scanning models described above to estimate the GSD, RER, and SNR. The mathematical relationship between these quantities and the image quality was developed specifically for underwater EOID systems [12,13]. The relationship between the image quality rating and the probability of identification is based on data collected at an 2001 ONR field test [6] and at various Navy exercises. An example display from a prototype tactical decision aid is shown on the right of Figure 1.

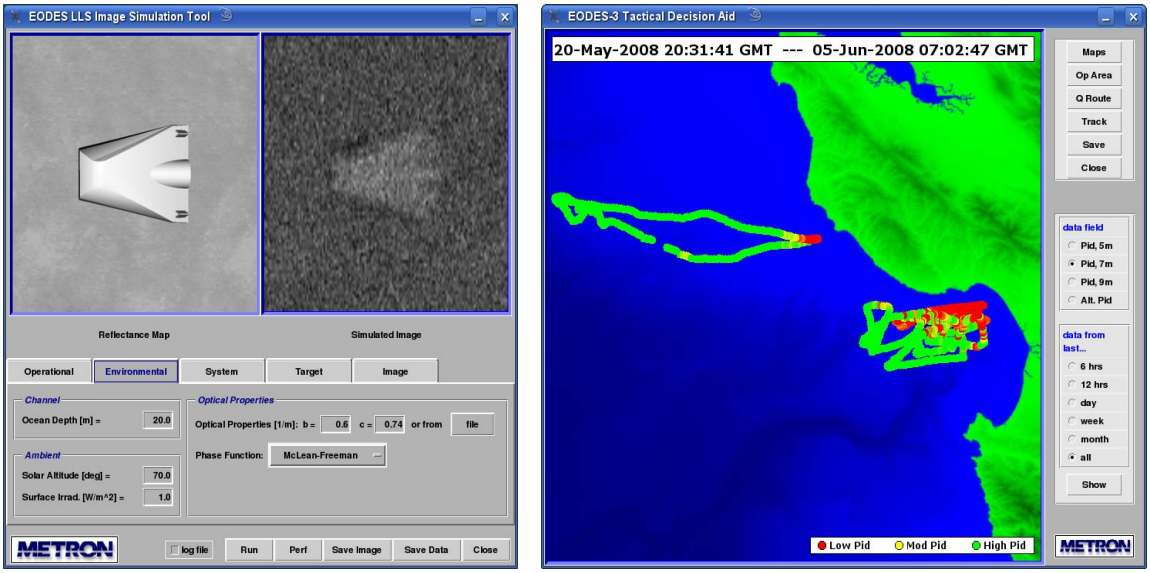

Figure 1: EODES image simulation GUI (left) with user inputs to specify water properties, system specifications, and operational settings. Prototype tactical decision aid (right) that displays a color-coded probability of identification for a system in the operational area.

WORK COMPLETED

Metron developed the EODES suite of electro-optical image simulation and performance prediction tools under this contract to the Office of Naval Research. This effort encompassed the analytical formulation of the physical models, their numerical implementation, and their validation against Monte Carlo simulations, laboratory experiments, and field test data. A performance prediction capability was also developed based on the underlying physical models, and this is currently being certified as the first Navy standard model for electro-optics to be included in the Oceanographic and Atmospheric

Master Library (OAML). The performance prediction algorithms are being incorporated into a real-time tactical decision aid at the Naval Oceanographic Office (NAVOCEANO), which is described in [15].

A key objective of this program was to implement high-fidelity numerical models based on the physics of radiative transfer in ocean environments and a detailed specification of system optics and receiver characteristics. Another important goal of the program was to incorporate these detailed physical models within a performance prediction methodology to provide estimates of EOID system effectiveness for mine countermeasures (MCM) operations in areas where the optical properties are known. The performance prediction products are provided to MCM commanders and mission planners to inform asset allocation and to aid in the development of effective tactics. The simulation models have also been used to help design next-generation EOID systems and to evaluate the performance of existing and prospective systems.

The EODES model suite includes simulation tools for several commercially available sensor technologies, including the Laser Line Scan (LLS) sensor used on the AN/AQS-24 and the Streak Tube Imaging Lidar (STIL) sensor used on the AN/AQS-20. A simulation tool for a prospective pulsed LLS sensor has also been developed. These simulation tools have graphical user interfaces, are portable across several computer platforms, and provide for detailed specification of the system specifications, operational parameters, and environmental conditions. The performance prediction tool has been packaged for inclusion in the OAML and is expected to be certified as a Navy standard model in October 2009. The entire suite of models has been thoroughly validated and documented and includes a 150-page manual, user-friendly applications, and user's guides.

RESULTS

This three-year project extended only a couple months into FY09. During that period the EODES software was packaged for submission to the OAML certification process. EODES is slated to be certified in October as the first Navy standard model for EOID systems to be included in the OAML. EODES performance prediction models are also being incorporated into tactical decision aids at NAVOCEANO and are also being used to provide EOID performance estimates based on satellite data for ocean optics at NRL-Stennis [16].

IMPACT/APPLICATIONS

EODES performance prediction models are expected to provide a new capability to tactical decision aids for mine warfare. EODES is also being used to evaluate the performance of current electro-optical systems and to design future systems for mine countermeasures applications.

TRANSITIONS

EODES performance prediction software is expected to transition to the Naval Oceanographic Office (NAVOCEANO). EODES models are also being used to evaluate performance of airborne LIDAR systems for the Naval Sea Systems Command (NAVSEA).

RELATED PROJECTS

N00014-09-C-0273, Electro-Optical System Simulation and Performance Prediction Extensions to EODES. This is a continuation of the EODES development where various extensions to the models will be added, and EODES models will also be used to analyze next-generation electro-optical identification systems for mine countermeasures. This project also supports OAML certification of new models and their transition to NAVOCEANO or other agencies.

N00014-08-M-0007, RIMPAC-08 Planning and Support and OAML Certification. This project involved the demonstration of EODES performance prediction software for MCM mission planning at the RIMPAC-08 Navy Exercise. The demonstration involved teams from NAVOCEANO, CNMOC, NRL-Stennis, Rutgers University, and Wet Labs. A full tactical performance prediction capability was implemented, including autonomous environmental data collection with Slocum gliders outfitted with WetLab optical sensors, near real-time command, control, and data telemetry through the NAVOCEANO Glider Operations Center (GOC), EOID performance prediction with EODES software, and tactical decision aids.

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